Tracking and Computer Vision to Control a Robotic Upper Limb Prosthetics

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Abstract:

This project discussed about a brain controlled robot based on Brain–computer interfaces (BCI). BCIs are systems that can bypass conventional channels of communication (i.e., muscles and thoughts) to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into commands in real time. With these commands a mobile robot can be controlled. The intention of the project work is to develop a robot that can assist the disabled people in their daily life to do some work independent on others. Brain signals will be sensed by the brain wave sensor and it will convert the data into packets and transmit through Bluetooth medium. Level analyzer unit (LAU) will receive the brain wave raw data and it will extract and process the signal using Matlab platform. Then the control commands will be transmitted to the robotic ARM module to process. With this entire system, we can pick an object and place it accordingly through the configured brain signals.

**Key words:** ARM, Zigbee, BCI, Pick and Place module.

I Introduction:

An EEG-based brain-controlled robot is a robot that uses EEG-based BCIs to receive human control (hereafter, brain controlled robots refer to EEG-based brain-controlled robots only). Two main classes of brain-controlled robots to assist disabilities are brain-controlled manipulators and mobile robots. One representative work of brain-controlled manipulators is the manipulator used within the FRIEND system developed by Graser which is able to show the brain controlled capabilities of robots out of a controlled laboratory situation. Brain-controlled mobile robots can be divided into two categories according to their operational modes. One category is called "direct control by the BCI," which means that the BCI translates EEG signals into motion commands to control robots directly.

Various approaches to implement this method are shown in Table I. One typical example is the work of Tanaka et al. [21], who first developed a brain-controlled robotic wheelchair whose left or right turning movements are directly controlled by corresponding motion commands translated from user brain signals while imagining left or right limb movements, and tested this system in real-world situations. However, the overall performance of these brain-controlled mobile robots mainly depends on the performance of the noninvasive BCIs, which are currently slow and uncertain. In other words, the performance of the BCI systems limits that of the robots.

Further, users need to issue motor control commands rather frequently, often causing user fatigue. To address the two questions aforementioned that the robots directly controlled by a BCI meet, so as to make the user be able to control the robot over a long period of time, the second group of brain-controlled robots has been developed from a perspective of shared control, where a user (using a BCI) and an intelligent controller (such as autonomous navigation system) share the control over the robots.

Block Diagram:
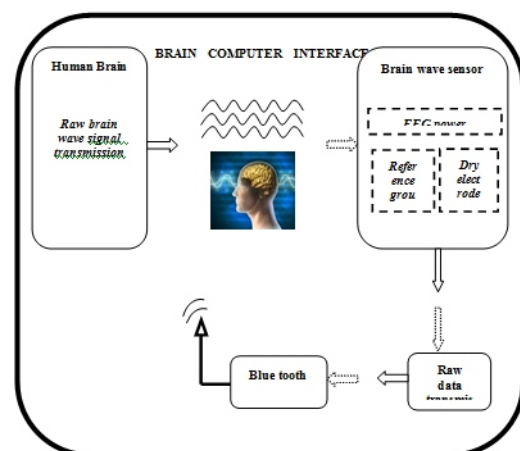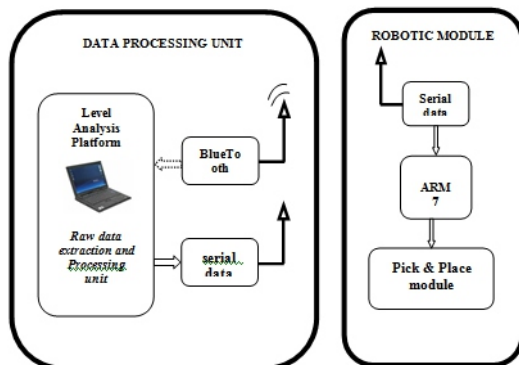
Fig1: BCI- Pick and Place.

II. Design and Implementation:

Electroencephalography (EEG) is the measurement of electrical activity in the living brain. In this project we used a brinwave sensor MW001 to analyse the EEG signals . This design discuss about processing and recording the raw EEG signal from the MindWave sensor in the MATLAB environment and through Zigbee transmission control commands will be passed to the Robot section. Mindwave sensors are not used in clinical use, but are used in the Brain Control Interface (BCI) and neurofeedback (one of biofeedback types). The BCI is a direct communication pathway between the brain and an external device.

Working Principle :

The principle of operation is quite simple. Two dry sensors are used to detect and filter the EEG signals. The sensor tip detects electrical signals from the forehead of the brain. At the same time, the sensor pick up ambient noise generated by human muscle, computers, light bulbs, electrical sockets and other electrical devices. The second sensor, ear clip, is a grounds and reference, which allows thinkgear chip to filter out the electrical noise.The device measures the raw signal, power spectrum (alpha, beta, delta, gamma, theta), attention level, mediation level and blink detection. The raw EEG data received at a rate of 512 Hz. Other measured values are made every second. Therefore, raw EEG data is a main source of information on EEG signals using MindWave MW001.

Design Theory:
A.Matlab Platform:
The MATLAB allows to include thinkgear.dll. This environment has broad support in toolbox, which makes it ideal for a scientific research.

This paper presents how recording and processing the raw EEG signal in MATLAB environment using MindWave sensor. The Communication Protocol, shows a system of digital rules for message exchange between MATLAB environment and MindWave MW001 device. This section also presents the main parameters of thinkgear library.

B.The Communications Protocol:

The proposed communications protocol is a system of simple rules for message exchanges between MATLAB and the EEG device. It consists of 7 basic steps, which are presented in following steps.

» Load ThinkGear library into MATLAB
» Get a connection ID handle to ThinkGear
» Attempt to connect the connection ID handle to serial port "COMx"
» Waiting to establish the connection
» Read packets from the connection
» Close the connection
» Unload ThinkGear library

In the first step are functions with parameters in the following order::

1. libisloaded('Thinkgear') – returns true if the Think-Gear library is loaded, and false otherwise.

2. loadlibrary('Thinkgear.dll','thinkgear.h') – loads the functions defined in the header file and found in the library. Now, the function calllib() can call a function in the ThinkGear library.

3. calllib('Thinkgear', 'TG_GetDriverVersion') – returns the version of loaded library.

In the next step, the function calllib('Thinkgear', 'TG_GetNewConnectionId') gets a new connection ID handle to ThinkGear. The value -1 is returned if too many connections have been created.In the ThinkGear library, the most important function is TG_Connect. This function needs 4 parameters: the connection ID, number of the serial port, Baud rate and type of data. The number of the serial port is given during the pairing of the device. The device can connect on modes 1200, 2400, 4800, 9600, 57600 and 115200 bits per second (bps). Here, we use the 9600 bps rate and stream 5V RAW mode, because these parameters have the minimum of transmission errors.

C.Pick and Place module section:

We can read the value of raw EEG signal with the maximum frequency of 512 Hz. Sampling frequency is set on 512 Hz, and we control time delays in sampling. The value of the signal and time are written to the array data. The data which are stored in array will be compared with the threshold points given by the user. In this project, the Matlab section waits for three consecutive blink in order to send the hardware activation signal. Then based on the attention level value Pick and Place module will be controlled. Based on the brain signal commands the object will be picked and placed by the ARM module.

III. System Hardware;
1.ARM-LPC2148:

The LPC2148 combine an ARM768E-S CPU core with two integrated TCM blocks operating at frequencies of up to 125 MHz, Full-speed USB 2.0 OTG and device controller, CAN and LIN, 56 kB SRAM, up to 768 kB flash memory, external memory interface, three 10-bit ADCs, and multiple serial and parallel interfaces in a single chip targeted at consumer, industrial and communication markets. To optimize system power consumption, the LPC2926/2927/2929 has a very flexible Clock Generation Unit (CGU) that provides dynamic clock gating and scaling.

The ARM768E-S is a general purpose 32-bit RISC processor, which offers high performance and very low power consumption. The ARM architecture is based on Reduced Instruction Set Computer (RISC) principles, and the instruction set and related decode mechanism are much simpler than those of microprogrammed Complex Instruction Set Computers (CISC). This simplicity results in a high instruction throughput and impressive real-time interrupt response from a small and cost-effective controller core.Amongst the most compelling features of the ARM768E-S are:

• Separate directly connected instruction and data Tightly Coupled Memory (TCM) interfaces
• Write buffers for the AHB and TCM buses

Pipeline techniques are employed so that all parts of the processing and memory systems can operate continuously.

The ARM768E-S is based on the ARMv5TE five-stage pipeline architecture. Typically, in a three-stage pipeline architecture, while one instruction is being executed its successor is being decoded and a third instruction is being fetched from memory. In the five-stage pipeline additional stages are added for memory access and write-back cycles. The ARM768E-S processor also employs a unique architectural strategy known as THUMB, which makes it ideally suited to high-volume applications with memory restrictions or to applications where code density is an issue. The key idea behind THUMB is that of a super-reduced instruction set. Essentially, theARM768E-S processor has two instruction sets:

• Standard 32-bit ARMv5TE set.
• 16-bit THUMB set.

2.Brain wave sensor:

Electroencephalography (EEG) is the measurement of electrical activity in the living brain. In this project we used a brinwave sensor MW001 to analyse the EEG signals . This design discuss about processing and recording the raw EEG signal from the MindWave sensor in the MATLAB environment and through Zigbee transmission control commands will be passed to the Robot section. Mindwave sensors are not used in clinical use, but are used in the Brain Control Interface (BCI) and neurofeedback (one of biofeedback types). The BCI is a direct communication pathway between the brain and an external device.

ThinkGear ASIC Module

• Directly connects to dry electrode (as opposed to conventional medical wet sensors)
• One EEG channel with three contacts: EEG; REF; and GND
• Improper fit detected through "Poor Signal Quality" warning from ASIC to reset if off the head for four consecutive seconds, or if it is receiving a poor signal for seven consecutive seconds
• Advanced filtering technology with high noise immunity
• Low power consumption suitable for portable battery-driven applications
• Max power consumption 15mA @ 3.3 V
• Raw EEG data output at 512 bits per second

Think Gear or TGAM Features + Technical Specifications:
Measures

• Raw brainwave signal
• Processing and output of EEG power spectrums (Alpha, Beta, etc.)
• Processing and output of NeuroSky proprietary eSense meter for Attention, Meditation, and other future meters
• EEG/ECG signal quality analysis (can be used to detect poor contact and whether the device is off the head)
• Eyeblink detection
Electrodes
• Maximum surface area of ~150mm2 (but less surface area is optimal)
• Ag/AgCl, Stainless Steel, Gold, or/and Silver (both solid and plated material works)
• EEG electrode located above the left or right eye on the forehead
• Ground and reference electrodes located behind the ear or at the earlobe
• Have enough pressure to prevent movement, with a minimum of 0.8 PSI

3.L293D:

L293D is a dual H-bridge motor driver integrated circuit (IC). Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors.L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in forward and reverse direction. The motor operations of two motors can be controlled by input logic at pins 2 & 7 and 10 & 15. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively.

DC motor:

DC motors are configured in many types and sizes, including brush less, servo, and gear motor types. A motor consists of a rotor and a permanent magnetic field stator. The magnetic field is maintained using either permanent magnets or electromagnetic windings..Motors are the devices that provide the actual speed and torque in a drive system.

This family includes AC motor types (single and multiphase motors, universal, servo motors, induction, synchronous, and gear motor) and DC motors (brush less, servo motor, and gear motor) as well as linear, stepper and air motors, and motor contactors and starters.

4.IEEE 802.15.4 Protocol:

The XBee/XBee-PRO RF Modules are designed to operate within the ZigBee protocol and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between remote devices. The modules operate within the ISM 2.4 GHz frequency band and are compatible with the following.

Advanced Networking & Security
•   Point-to-point topology
•   point-to-multipoint topology
•   Self-routing, self-healing and fault-tolerant
•   mesh networking
Low Power
•   TX Current: 295 mA
•   RX Current: 45 mA
Power-down Current: < 1 μA

IV. System Software:

MATLAB's Graphical User Interface Development Environment (GUIDE) provides a rich set of tools for incorporating graphical user interfaces (GUIs) in M-functions. Using GUIDE, the processes of laying out a GUI (i.e., its buttons, pop-up menus, etc.)and programming the operation of the GUI are divided conveniently into two easily managed and relatively independent tasks.

Role of Matlab in BCI:

The MATLAB allows to include thinkgear.dll. This environment has broad support in toolbox, which makes it ideal for a scientific research. This paper presents how recording and processing the raw EEG signal in MATLAB environment using MindWave sensor. The Communication Protocol, shows a system of digital rules for message exchange between MATLAB environment and MindWave MW001 device. This section also presents the main parameters of thinkgear library.

The connection is established through command:calllib ('Thinkgear','TG_Connect',Id,ComPortName,TG_BAUD_115200,TG_ STREAM _5VRAW). In the next step, we must attempt to read a Packet of data from the connection. We use the TG_ReadPackets() function with ID parameter and number of packet to read. The command calllib('Thinkgear','TG_ReadPackets', Id,1) returns false for error, and otherwise true. The function TG_GetValueStatus() checks if a value has been updated by TG_ReadPackets(). If this function returns true, we can use TG_GetValue() function to get the updated value of the raw EEG signal.
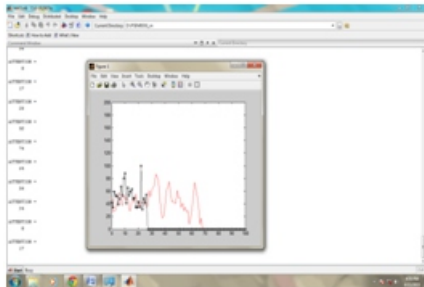
Fig: Brian signal representation in MATLAB

The above graph representation includes the attention value and blink strength. Based on this signals Pick and Place module will be controlled. Based on the brain signal commands the object will be picked and placed by the ARM module.

V. Conclusion:

This project discussed about a brain controlled robot based on Brain–computer interfaces (BCI). BCIs are systems that can bypass conventional channels of communication (i.e., muscles and thoughts) to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into commands in real time. With these commands an object can be picked and placed in any environment.This project will become an assistive technology for disabled people in future.

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